Section 7.15
Wildland Fire Use (WFU)

(Revised Methodology May 2006)

EMISSION INVENTORY SOURCE CATEGORY
Areawide Sources / Miscellaneous Processes / Wildland Fire Use (WFU)

EMISSION INVENTORY CODES (CES CODES) AND DESCRIPTION

670-667-0200-0000 (90142) Wildland Fire Use (WFU)

METHODS AND SOURCES

This source category provides emission estimates from Wildland Fire Use (WFU) fires. A WFU is a naturally ignited lightning fire that is managed for resources benefit. The emission estimation methodology described here is the same method used to calculate emissions for the Wildfire category, listed under Natural Sources in the emission inventory. The WFU emission inventory category was created in 2004, and inventory back populated to 1994 where data were available.

OVERVIEW OF ESTIMATION METHODOLOGY

WFU emissions are calculated using the Geographic Information System (GIS) based Emission Estimating System (EES) model developed for ARB by UC Berkeley's Center for the Assessment and Monitoring of Forest and Environmental Resources (CAMFER) laboratory (Clinton et al. 2003, Scarborough et al. 2001). The CAMFERS EES implements the Forest Service First Order Fire Effects Model(1) (FOFEM 4.0, Reinhardt et al. 1997) methods.

Known fire perimeters are overlaid on California vegetation (Davis et al. 1998), establishing the specific vegetation consumed in each fire. Fuel loadings are assigned to the specific vegetation that burned in each fire. The EES then calculates the tons of fuel consumed by the fire, which is influenced by moisture condition. The EES then applies the appropriate emission factor to generate smoke emissions per WFU event (see example calculation on page 6). Tables 3 and 4 attached represent 2002 WFU activity.

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(1) FOFEM is a fuel consumption and smoke production model developed by USDA – Forest Service, Rocky Mountain Research Station, Missoula Fire Laboratory. The FOFEM model determines pre-burn fuel loading, fuel mass consumed, and smoke emissions generated per fire acre burned.

EMISSION ESTIMATION METHODOLOGY

Activity Data - WFU Perimeters. WFU footprints and ignition dates information were gathered by contacting individual land management agencies and from the California Department of Forestry and Fire Protection (CDF) Fire and Resources Assessment Program (FRAP) fire perimeter GIS spatial file. WFUs were tagged with code "20" in the source column of the attribute table.

Emission Factors and Pollutants. The CAMFER EES calculates emissions for PM10, PM2.5, CO, NOx, SO2, N20, NH3, CH4, and TNMHC for each fuel component. There are ten fuel components that represent each vegetative landcover in California: duff; litter; 0-1 inch, 1-3 inch, and 3+ inch diameter dead woody fuels; herbaceous, shrub, regeneration; and canopy fuels. There are two components that define canopy fuels: canopy branchwood, which is the ladder branches along the tree that lead to the canopy, and canopy foliage, which are the treetops. Duff is partially decomposed organic material of the forest floor that lies beneath the litter. Litter is the freshly fallen twigs, cones, needles, and leaves. Tree regeneration represents saplings and new growth. Herbaceous fuel represents grasslands and the green vegetation that comprise the forest understory. Shrubs are woody plants of relatively low height. Emission factors for these fuel components are grouped into six categories.

The CAMFER EES model uses FOFEM equations to estimate emissions. Emissions factors for PM10, PM2.5, and CO are based on a function of combustion efficiency and the ratio of flaming and smoldering phases of fire under different moisture regimes (Reinhardt et al. 1997). CAMFER further expanded the suite of emission factors by using an "emission ratio" approach (Lobert et al. 1991). The approach is based on the observation that emissions correlate with CO or CO2 depending on whether the compound is evolved primarily in the flaming or smoldering phase of fire. For a more detailed explanation of how emission factors are derived, see the references.

Table A. Emission factors in lbs/ton of fuel consumed, by fuel component, for wet, moderate, and dry burn conditions.

	PM10			PM2.5			CO			CH4		
Fuel component	**Wet**	**Mod**	**Dry**	**Wet**	**Mod**	**Dry**	**Wet**	**Mod**	**Dry**	**Wet**	**Mod**	**Dry**
Litter, wood 0-1 in	9.3	9.3	9.3	7.9	7.9	7.9	52.4	52.4	52.4	2.1	2.1	2.1
Wood 1-3 in	14.0	14.0	14.0	11.9	11.9	11.9	111.4	111.4	111.4	4.5	4.5	4.5
Wood 3+ in	26.6	21.6	19.1	22.5	18.3	16.2	268.9	205.8	174.4	10.8	8.2	7.0
Herb, shrub, regen	25.1	25.1	25.1	21.3	21.3	21.3	249.2	249.2	249.2	10.0	10.0	10.0
Duff	28.2	30.4	30.4	23.9	25.8	25.8	288.6	316.1	316.1	11.5	12.6	12.6
Canopy fuels	25.1	25.1	25.1	21.3	21.3	21.3	249.2	249.2	249.2	10.0	10.0	10.0
	TNMHC			**NH3**			**NOx**			**SO2**		
Fuel component	**Wet**	**Mod**	**Dry**	**Wet**	**Mod**	**Dry**	**Wet**	**Mod**	**Dry**	**Wet**	**Mod**	**Dry**
Litter, wood 0-1 in	3.7	3.7	3.7	0.5	0.5	0.5	8.2	8.2	8.2	2.5	2.5	2.5
Wood 1-3 in	7.8	7.8	7.8	1.1	1.1	1.1	8.0	8.0	8.0	2.5	2.5	2.5
Wood 3+ in	18.8	14.4	12.2	2.7	2.1	1.7	7.3	7.6	7.7	2.2	2.3	2.4
Herb, shrub, regen	17.4	17.4	17.4	2.5	2.5	2.5	7.4	7.4	7.4	2.3	2.3	2.3
Duff	20.2	22.1	22.1	2.9	3.2	3.2	7.2	7.1	7.1	2.2	2.2	2.2
Canopy fuels	17.4	17.4	17.4	2.5	2.5	2.5	7.4	7.4	7.4	2.3	2.3	2.3

Fuel Loading and Fuel Consumption. Each vegetation type in the California GAP layer was assigned FOFEM fuel loading values, defined by the tons of each fuel component per acre that comprise each landcover type. Fuel consumption and combustion efficiency are the two processes that determine the emissions from the fuel burned. Fuel consumption is the amount, in tons, of fuel consumed by fire. The consumption assumptions for each fuel component is as follows: litter and herbaceous fuels assumes 100% consumption; shrub and tree regeneration fuels assumes 60% consumption; wood 0-1 inch assumes 90% consumption; wood 1-3 inch assumes 65% fuel consumption; canopy fine branchwood assumes 50% consumption; and canopy foliage assumes 100% consumption. Wood 3+ inches and duff consumption depends on fuel moisture.

Thousand-Hour Fuel Moisture. Wood 3+ inches (thousand-hour fuels) moisture is defined as the National Fire Danger Rating System Thousand-Hour (NFDR-TH) fuel moisture. NFDR-TH and moisture conditions affects fuel consumption, as well as combustion efficiency, which is defined as the portion of CO or CO2 released from fuel consumed. Combustion efficiency is directly related to the portion of consumption that happens in either the flaming or smoldering phase of fire. For example, the lower the moisture, the more efficient the combustion, and the greater the proportion of consumption in the flaming phase of fire. Likewise, the higher the moisture, a greater proportion of consumption takes place in the smoldering phase of fire, and the lower the combustion efficiency.

The EES model is especially sensitive to the fuel moisture input. NFDR-TH values represent the fuel moisture of large dead logs on the forest floor, which can vary considerably across California. In order to improve WFU emission estimation, CAMFER created monthly averaged moisture grids, which provide a more refined distribution of thousand-hour fuel moistures Statewide. The fuel moisture grid is based on Forest Service NFDR-TH graphics averaged for the year 2000. A thorough explanation of how the gridded NFDR-TH input layer was developed is provided in the Wildland II report (Clinton et al. 2003). Archived Forest Service NFDR-TH maps can be accessed at the Wildland Fire Assessment System (WFAS) web page at: http://www.fs.fed.us/land/wfas/ (Burgan et al. 1997).

California Gap Analysis Project (GAP) Landcover Map. The GAP landcover map is used as the vegetation input (Davis et al. 1998). California's GAP coverage is comprised of over 21,000 vegetation polygons, aggregated into over 200 natural community types. The minimum mapping unit is 1 kilometer. Each GAP polygon is comprised of up to three vegetation assemblages (primary, secondary, and tertiary), with each type comprising a fraction of the total polygon area. The EES overlays the WFU footprint with the GAP vegetation, discerning the specific landcover types and calculating the acres of each flora burned in each fire.

TEMPORAL INFORMATION

Monthly variations are calculated by using month specific WFUs and month specific thousand-hour fuel moistures. For modeling purposes, gridded emissions are provided.

ASSUMPTIONS AND LIMITATIONS

- The FRAP dataset is populated with the information submitted by land management agencies, therefore accuracy and consistency can vary by area and year. The FRAP GIS layer is updated annually and provides the most comprehensive dataset available.
- FOFEM assumes 100% of the burn area experiences fire.
- CAMFER model default settings are as follows:
  - Fuel category: Natural
  - Dead fuel adjustment factor: Typical
  - Moisture conditions: Dry
  - Fire intensity: Extreme
  - Fire will burn tree crown: Yes
  - Tree crown biomass burning: Typical
  - Herbaceous density: Typical
  - Shrub density: Typical
  - Tree regeneration density: Typical
  - NFDR-TH moisture percent: Monthly Grid Input*

**Gridded thousand-hour fuel moisture values are averaged by month based on year 2000 data.*

CHANGES IN METHODOLOGY

WFU is a new emission inventory category created in 2004. However, the emission inventory was populated using historic WFU data where fire data were available.

EXAMPLE CALCULATION

Below is an example calculating PM10 emissions for the Mud WFU that burned in Alpine County from August 31, 2003 to October 3, 2003. The EES model overlays the Mud WFU perimeter on California vegetation yielding the acres of each vegetation type burned in the fire, as depicted in the graphic below. The Mud WFU footprint was 4,324 acres and burned two vegetation types: 2,467 acres were on red fir (or lodgepole pine)-western white pine and 1,857 acres were on jeffrey pine-fir forest. Each vegetation cover type has fuel loading characteristics assigned by fuel component, as shown in Table 1 below.

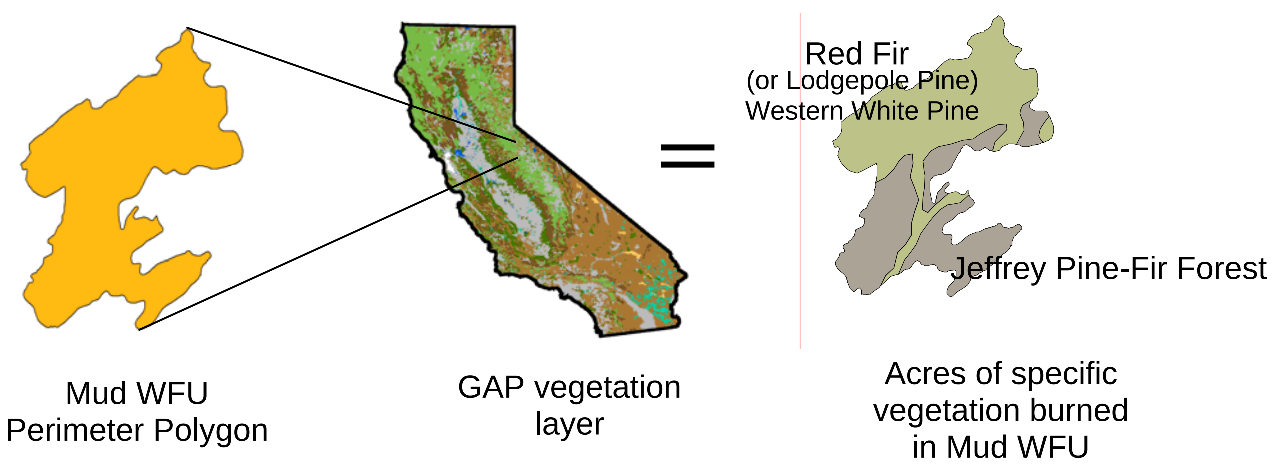

Table 1. Acres burned and fuel loading by fuel component for each vegetation type burned in the Mud WFU.

Fuel Components	Jeffrey Pine-Fir Forest	Red Fir (or Lodgepole Pine) Western White Pine
Acres	**1857**	**2467**
Litter	1.50	0.70
Wood 0-1 inch	1.00	1.10
Wood 1-3 inch	1.50	0.00
Wood 3+ inches	20.00	3.00
Herbs	0.20	0.00
Shrubs	0.25	0.00
Regen	0.15	0.00
Duff	40.00	11.00
Canopy foliage	6.00	4.00
Lateral fuels	3.00	2.80

Table 2 below shows the steps to calculate PM10 emissions for the Mud WFU: 1) The number of acres for each vegetation type burned and the fuel loading (shown in Table 1) are multiplied; 2) Fuel loading for each vegetation type are summed; 3) The percent fuel consumption for wood 3+ inch and duff are calculated and/or default consumption assumptions are applied to calculate fuel consumption; 4) Emission factors are applied to calculate pounds of PM10 emitted; and 5) Pounds are converted to tons.

Table 2. Total fuel loading for the Mud WFU, percent consumption, total fuel consumption, PM10 emission factors, and PM10 emissions by fuel component for the Mud WFU.

STEPS	1		2	3		4		5
	Jeffrey Pine-Fir Forest	Red Fir (or Lodgepole Pine) Western White Pine	Mud WFU Fuel Loading (tons)	Fuel Consumption (percent)	Fuel Consumed (tons)	PM10 Emission Factors (lbs/ton)	PM10 Emissions (lbs)	PM10 Emissions (tons)
Fuel Components	Acres* Fuel Loading							
Litter	2,787	1,727	4,513.8	100%	4513.8	9.3	41,978.1	21.0
Wood 0-1 inch	1,858	2,714	4,571.8	90%	4114.6	9.3	38,265.9	19.1
Wood 1-3 inch	2,787	0	2,786.7	65%	1811.3	14.0	25,358.8	12.7
Wood 3+ inches	37,156	7,402	44,557.5	100%(1)	44557.5	19.1(3)	851,049.2	425.5
Herbs	372	0	371.6	100%	371.6	25.1	9,326.1	4.7
Shrubs	464	0	464.4	60%	278.7	25.1	6,994.6	3.5
Regen	279	0	278.7	60%	167.2	25.1	4,196.7	2.1
Duff	74,311	27,140	101,451.5	61%(2)	62245.0	30.4(3)	1,892,248.4	946.1
Canopy foliage	11,147	9,869	21,015.8	100%	21015.8	25.1	527,497.6	263.7
Lateral fuels	5,573	6,908	12,481.7	50%	6240.9	25.1	156,645.9	78.3
							3,553,561.3	1776.8

(1) Wood 3+ inch percent consumption equations (Brown et al. 1991):
Diameter reduction = 7.917 - [0.252 * (1.4 * NFDTH)] + (0.34 * PDIA)
Fraction consumption = 1 - ((PDIA - Diameter Reduction) / PDIA)2
PDIA (quadratic mean preburen diameter) = 5 *(constant)*
Mud WFU NFDTH = 12.8
(2) Duff percent consumption equation (Brown et al. 1993):
Duff reduction = (114.7 - (4.2 * NFDTH)) / 100
Mud WFU NFDTH = 12.8
(3) Moisture conditions = "dry"

REFERENCES

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PREPARED BY

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Table
Wildland Fire Use (WFU)
EIC: 670-667-0200-0000 CES: 90142
2002 Wildland Fire Use - Activity Data (acres) - Monthly emissions as percent of total emissions

A	District	C I	Activity Dat	Ja	Fe	Ma	Ap	Ma	Ju	Ju	Au	Se	Oc	No	Dec
GB	GREAT BASIN UNIFIED	2	0												
		14	0												
		26	0												
LC	LAK	17	0												
LT	EL	9	0												
	PLACE	31	0												
M	AMADO	3	0												
	CALAVERA	5	0												
	EL	9	0												
	MARIPOSA	22	1	0.0	0.0	0.0	0.0	0.0	0.0	100.0	0.0	0.0	0.0	0.0	0.0
	NORTHERN SIERRA	29	0												
	PLACE	31	0												
	NORTHERN SIERRA	32	0												
	NORTHERN SIERRA	46	0												
	TUOLUMN	55	2478	0.0	0.0	0.0	0.0	0.0	0.0	100.0	0.0	0.0	0.0	0.0	0.0
M	KER	15	0												
	ANTELOPE VALLEY	19	0												
	MOJAVE DESERT	33	0												
	SOUTH	33	0												
	MOJAVE DESERT	36	0												
NC	NORTH COAST UNIFIED	8	0												
	NORTH COAST UNIFIED	12	0												
	MENDOCINO	23	0												
	NORTHERN SONOMA	49	0												
	NORTH COAST UNIFIED	53	0												
NCC	MONTEREY BAY UNIFIED	27	0												
		35	0												
		44	0												
NE	LASSE	18	0												
	MODO	25	0												
	SISKIYOU	47	0												
S	SOUTH	19	0												
		30	0												
		33	0												
		36	0												
SC	SAN LUIS OBISPO	40	0												
	SANTA BARBARA	42	0												
	VENTUR	56	0												
S	SAN DIEGO	37	0												
S	BAY AREA	1	0												
		7	0												
		21	0												
		28	0												
		38	0												
		41	0												
		43	0												
		48	0												
		49	0												
SJ	SAN JOAQUIN VALLEY UNIFIED	10	1560	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100.0	0.0	0.0	0.0	0.0
		15	0												
		16	0												
		20	63	0.0	0.0	0.0	0.0	0.0	0.0	100.0	0.0	0.0	0.0	0.0	0.0
		24	0												
		39	0												
		50	0												
		54	9	0.0	0.0	0.0	0.0	0.0	100.0	0.0	0.0	0.0	0.0	0.0	0.0
S	IMPERIAL	13	0												
	SOUTH	33	0												
S	BUTT	4	0												
	COLUS	6	0												
	GLEN	11	0												
	PLACE	31	0												
	SACRAMENTO METRO	34	0												
	SHAST	45	0												
	YOLO-SOLANO	48	0												
	FEATHER RIVER	51	0												
	TEHAM	52	0												
	YOLO-SOLANO	57	0												
	FEATHER RIVER	58	0												

Table
Wildland Fire Use (WFU)
EIC: 670-667-0200-0000 CES: 90142
2002 Wildland Fire Use - Activity Data (acres) - Emissions (tons/year)

A	District	C I	Activity Dat	PM1	PM2	CO	CH	TNMHC	NH	NO	SO2	Total
GB	GREAT BASIN UNIFIED	2	0									
		14	0									
		26	0									
LC	LAK	17	0									
LT	EL	9	0									
	PLACE	31	0									
M	ANTELOPE VALLEY	19	0									
	KER	15	0									
	MOJAVE DESERT	33	0									
	MOJAVE DESERT	36	1	0.7	0.6	7.7	0.3	0.5	0.0	0.2	0.0	*10.4*
	SOUTH	33	0									
M	AMADO	3	0									
	CALAVERA	5	0									
	EL	9	0									
	MARIPOSA	22	2478	1381.8	1172.5	13576.0	543.0	950.3	135.7	427.3	131.6	*18318.67*
	NORTHERN SIERRA	29	0									
	NORTHERN SIERRA	32	0									
	NORTHERN SIERRA	46	0									
	PLACE	31	0									
	TUOLUMN	55	0									
NCC	MONTEREY BAY UNIFIED	27	0									
		35	0									
		44	0									
NC	MENDOCINO	23	0									
	NORTH COAST UNIFIED	8	0									
	NORTH COAST UNIFIED	12	0									
	NORTH COAST UNIFIED	53	0									
	NORTHERN SONOMA	49	0									
NE	LASSE	18	0									
	MODO	25	0									
	SISKIYOU	47	0									
S	BUTT	4	0									
	COLUS	6	0									
	FEATHER RIVER	51	0									
	FEATHER RIVER	58	0									
	GLEN	11	0									
	PLACE	31	0									
	SACRAMENTO METRO	34	0									
	SHAST	45	0									
	TEHAM	52	0									
	YOLO-SOLANO	48	0									
	YOLO-SOLANO	57	0									
S	IMPERIAL	13	0									
	SOUTH	33	0									
S	SAN DIEGO	37	0									
S	BAY AREA	1	0									
		7	0									
		21	0									
		28	1560	928.2	787.6	9192.7	367.7	643.4	91.9	277.2	85.4	*12374.5*
		38	0									
		41	0									
		43	63	13.2	11.2	131.2	5.2	9.1	1.3	3.9	1.2	*176.6*
		48	0									
		49	0									
SJ	SAN JOAQUIN VALLEY UNIFIED	10	0									
		15	9	5.3	4.5	52.5	2.1	3.6	0.5	1.6	0.5	*70.8*
		16	0									
		20	0									
		24	0									
		39	0									
		50	0									
		54	0									
SC	SAN LUIS OBISPO	40	0									
	SANTA BARBARA	42	0									
	VENTUR	56	0									
S	SOUTH	19	0									
		30	0									
		33	0									
		36	0									
STATE TOTALS			*4111*	*2329.504*	*1976.651*	*22960.377*	*918.41514*	*1607.22625*	*229.603*	*710.521*	*218.914*	*30951.2*

County ID	
1	ALAMEDA
2	ALPINE
3	AMADOR
4	BUTTE
5	CALAVERAS
6	COLUSA
7	CONTRA COSTA
8	DEL NORTE
9	EL DORADO
10	FRESNO
11	GLENN
12	HUMBOLDT
13	IMPERIAL
14	INYO
15	KERN
16	KINGS
17	LAKE
18	LASSEN
19	LOS ANGELES
20	MADERA
21	MARIN
22	MARIPOSA
23	MENDOCINO
24	MERCED
25	MODOC
26	MONO
27	MONTEREY
28	NAPA
29	NEVADA
30	ORANGE
31	PLACER
32	PLUMAS
33	RIVERSIDE
34	SACRAMENTO
35	SAN BENITO
36	SAN BERNARDINO
37	SAN DIEGO
38	SAN FRANCISCO
39	SAN JOAQUIN
40	SAN LUIS OBISPO
41	SAN MATEO
42	SANTA BARBARA
43	SANTA CLARA
44	SANTA CRUZ
45	SHASTA
46	SIERRA
47	SISKIYOU
48	SOLANO
49	SONOMA
50	STANISLAUS
51	SUTTER
52	TEHAMA
53	TRINITY
54	TULARE
55	TUOLUMNE
56	VENTURA
57	YOLO
58	YUBA

Air Basin ID	
GBV	GREAT BASIN VALLEYS
LC	LAKE COUNTY
LT	LAKE TAHOE
MD	MOJAVE DESERT
MC	MOUNTAIN COUNTIES
NCC	NORTH CENTRAL COAST
NC	NORTH COAST
NEP	NORTHEAST PLATEAU
SV	SACRAMENTO VALLEY
SS	SALTON SEA
SD	SAN DIEGO COUNTY
SF	SAN FRANCISCO BAY AREA
SJV	SAN JOAQUIN VALLEY
SCC	SOUTH CENTRAL COAST
SC	SOUTH COAST